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Office européen des brevets



(11) Publication number:

**0 476 693 A2**

(12)

**EUROPEAN PATENT APPLICATION**(21) Application number: **91116052.1**(51) Int. Cl.<sup>5</sup>: **C03B 23/025**(22) Date of filing: **20.09.91**(30) Priority: **21.09.90 FI 904653**(72) Inventor: **Lehto, Esko Olavi**(43) Date of publication of application:  
**25.03.92 Bulletin 92/13****Toosintie 15 A 1****SF-36240 Kangasala 4(FI)**(84) Designated Contracting States:  
**CH DE FR GB IT LI**

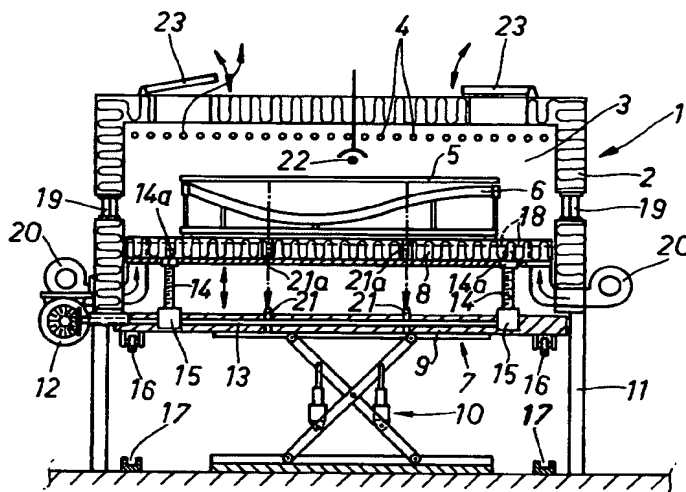
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(54) **Method and apparatus for bending a glass sheet.**

(57) The invention relates to a method and apparatus for bending a glass sheet. A glass sheet (5) is supported on a bending mould (6) in a heating furnace and heated close to a softening temperature by means of a heating field generated by heating

elements (4). Glass sheet (5) is placed adjacent to the heating field whose energy distribution is adjusted as desired. Glass sheet (5) is controllably pulled away from the heating field as the glass heats up and begins to bend.

**Fig. 1****EP 0 476 693 A2****BEST AVAILABLE COPY**

The present invention relates to a method for bending a glass sheet, wherein a glass sheet is supported on a bending mould in a heating furnace and heated close to a softening temperature by means of a heating field generated by heating element. The invention relates also to an apparatus for bending a glass sheet, said apparatus comprising a heating furnace, a mould for supporting a glass sheet in the heating furnace, as well as an array of heating elements for generating a heating field. The heating elements are typically elongated electric resistance elements, the invention not being limited, however, to the use of such elements only but also other types of heating elements, such as gas burners can be employed.

The prior art methods and equipment, based on gravitational bending of glass, can only be used for bending relatively simple configurations. Complex bending shapes, wherein the bending is effected with a relatively small bending radius and often also about two crosswise bending axes, have necessarily been bent by embossing between whole-surface moulds. This requires inconvenient and expensive mould technology, wherein a further problem is a contact between mould and glass.

One of the most important qualities in a heating furnace is the proper focusing of heat in terms of both quantity and timing. With the prior art methods and equipment, it is difficult or impossible to achieve the properly proportioned and timed focusing of heat as a result of e.g. the following reasons:

- distance between glass and heating resistances is too long
- distance between glass and heating resistances cannot be adjusted during a bending operation
- mutual distance of heating resistances is too long
- parallel heating resistances are not capable of focusing heat on a desired spot
- measuring often involves just overall temperature, although a bending process should be controlled on the basis of glass temperature
- the heat radiation energy emitted by an individual heating resistance is not correctly dimensioned.

An object of the invention is to provide an improved method and apparatus for eliminating the above deficiencies as completely as possible in a manner that the heating effect can be applied to glass by focusing as correctly as possible locally, quantitatively, and in terms of timing.

This object is achieved on the basis of the characterizing features set forth in the annexed claims.

As the invention makes it possible to control the focusing of heat on glass, the glass can be

subjected to bending relative complex bending shapes therein even by mere gravitational bending with the glass supported on a ring mould. If particularly difficult bending shapes are required, it is of course possible to employ whole or partial surface moulds on one or either side of a glass sheet. Examples of such moulds are disclosed in the Applicant's prior FI Patent applications 901601, 901602 and 901603. When applying these mould designs, the use of an upper mould shall not be necessary until at the end of a bending operation for continued bending and finishing the shape.

Although the invention shall be described in association with an individual separate furnace, it is obvious that the invention is applicable also in connection with current bending furnaces to replace their bending station, serving as an extension of the actual heating furnace or a special section included therein.

One embodiment of the invention will now be described in more detail with reference made to the accompanying drawings, in which

- fig. 1 shows an apparatus of the invention in a schematic vertical section.
- Fig. 2 is a schematic view of the various operating stages a), b) and c) for the apparatus.
- Fig. 3 is a block diagram showing the operating control for a method and apparatus of the invention.
- Fig. 4 is a more detailed view of the arrangement of resistances for a heating field.

Next described will be the general design of the apparatus. A bending furnace indicated by reference numeral 1 is fixedly mounted on a flat base and supported by legs 11. The furnace includes walls 2 which are provided with a solid external steel frame carrying an internal heat insulation. The top section of a furnace space 3 is provided with a plurality of densely mounted elongated resistance heating elements 4, whose more detailed arrangement will be explained hereinafter with reference to fig. 4.

A glass sheet 5 subjected to bending is supported on a mould 6, which can be a ring mould, a whole-surface mould or a combination of a ring mould and a partial-surface mould.

A base carriage 7 is shown in its hoisted position with its heat-insulated floor 8 in furnace space 3 and a lower floor 9, providing the body of a base carriage, resting tightly against the bottom edges of furnace walls 2. A hoist 10 can be used for lifting and lowering the entire carriage 7, so that in a top position said floor 9 is positioned as shown in fig. 1 and in a bottom position, wheels 16 are in contact with rails 17 for pushing said base carriage 7 along with its mould and glass out of the furnace (see fig. 2, stage a).

The movable floor 8 facilitates adjustment of the distance of glass 5 from resistances 4. A drive shaft 13 rotated by a power unit 12 rotates lifting screws 14, which are engaged with lifting nuts 14a carried by floor 8. The rotation of screws 14 is effected by means of gear or worm screw drives included in housings 15. Housings 15 are secured to floor 9 and the lower ends of screws 14 are journaled against the base of housings 15 and the upper ends are allowed to extend through floor 8. Of course, the opposite arrangement is also possible, whereby the upper ends of screws 14 are journaled to floor 8 in a rotatable but axially fixed manner and the screw rod extends through housing 15. Lifting screws 14 can also be replaced by gear racks or other prior known hoisting means. Two drive shafts 13 are required at both ends of a furnace, the number of lifting screws 14 thus being four. In order to provide a stepless adjustment for the traveling speed of floor 8 as well as for the distance of glass sheet 5 from resistances 4, said driving unit 12 comprises one of the following: a hydraulic variator, a direct-current motor, a servo motor or a stepping motor. On the other hand, said power unit 12 is operated by means of a bending-process controlling computer 26 (fig. 2), as explained in more detail hereinafter.

In view of measuring the temperature, said floor 9 of carriage 7 is provided with two infrared thermometers (pyrometers) 21 for measuring the real glass temperature directly from the glass surface. For this purpose, said movable floor 8 is provided with openings 21a. In addition, said furnace 3 is provided with a thermo-element 22 for measuring the general furnace temperature.

In order to obtain a desired and controlled cooling rate for glass following a bending operation, there are two cooling-air fans 20 adapted to blast cooling air through passages or recesses in the edges of floor 8. Fans 20 can be mounted either on the lower edge of furnace wall 2, as shown in fig. 1, or also on floor plate 9 of carriage 7. The rotating speed of fans 20 is adjustable in a stepless fashion. In addition, the roof of furnace 1 is provided e.g. in four corners with openable and closeable cooling gates 23 for letting hot air out of the furnace. Gates 23 are each subjected to individual control for attaining a desired cooling rate.

The bending furnace is provided on all four sides with windows 19 which offer a good visibility to the furnace interior. The furnace is also fitted with an effective illuminator providing a good visibility inside the furnace even in its cold condition (during a bending operation, the hot-glowing resistances also add to visibility). The spaces between furnace legs 11 can be provided with protective walls in order to avoid possible damages caused by a movable base carriage and a hoist mecha-

nism included in the furnace. One of the protective walls, indicated by reference numeral 30 in fig. 2, is movable up and down along guides whereby, in the top position of protective wall 30, said base carriage 7 can be pulled out for loading or unloading (fig. 2, stage a)) and, in the bottom position of wall 30, the lower section of the furnace is completely protected.

Figs. 3 and 4 illustrate the operating control and arrangement of resistances. As shown particularly in fig. 4, elongated heating resistance elements 4.1 and 4.2 are symmetrically positioned in two half-fields in a manner that the longitudinal direction of elements 4.1 forms an acute angle with that of elements 4.2. Between these resistance fields is yet a third resistance field, the direction of resistances 4.3 therein being crosswise or longitudinal relative to the longitudinal direction of the furnace. The array of these mid-section resistances 4.3 need not be so dense, since sufficient heating effect travels from the edges towards the centre and relatively the more the further away from the resistance field a glass sheet is located.

In addition, the resistance line provided by each resistance 4.1 and 4.2 is of ternary configuration, i.e. three resistance that can be separately switched on and off are mounted on a common line one after the other. The power dimensioning and arrangement of resistances 4.1 and 4.2 and 4.3 are carried out in a manner that the heating effect thereof can be focused in the best possible degree on a desired spot for a controlled bending operation. This object is not only achieved by the large number and density of resistances but also, and in particular, the V-shaped relative disposition of resistances 4.1 and 4.2. The V-angle must be typically within the range of 20 - 50°, preferably 30 - 40°, e.g. 35°. The total number of individual resistances that can be separately switched on and off is over 200, preferably over 300, e.g. 350.

In fig. 3, reference numeral 24 designates a block, which houses e.g. relay-controlled switches or contactors, one for each resistance 4. The control of switches or contactors 24 is effected by means of controllable logic circuits 25, which read the ON/OFF-states of individual resistances 4 and which inform a process-controlling computer 26 of a given circuit pattern in the resistance field. This is shown on the display of computer 26 e.g. by variation of the colour of switched-on resistances. Thus, the display includes a graphic representation according to fig. 4 over the entire resistance field in a manner that each resistance is visible.

On top of this resistance field, it is possible to display an outline 5.1 for a glass sheet to be bent, whereby the experimental set-up of a bending program for each bending shape and glass thickness separately is considerably facilitated.

For an experimental search of bending parameters, the apparatus is further provided with a control panel 28 which carries a schematic drawing of the arrangement of resistances and each resistance is individually numbered. Aligned with each resistance are switches 29 for switching individual resistances on and off. Thus, the control panel 28 can be to manually set up any desired heating pattern. A signal light is switched on control panel 8 from each switched-on resistance. The ON/OFF-positions of switches 29 and the variation thereof during various stages of a heating and bending cycle can be recorded in the program store of computer 26. Thus, the manually controlled energy distribution of a heating field and the changing thereof can be programmably reproduced. The power unit 12 for lifting and lowering said floor 8 can be controlled either from an operating panel 27 manually or by repeating the previous manual control, which is recorded in the program store of computer 26. One useful computer program is e.g. designated "Screen Ware", which is commercially available control-room software for PC/AT micro-computers. This program includes an appropriate flexible configuration of displays, data logging and processing as well as real-time displays. This program can be directly linked with programmable logic circuits 25. In the test apparatus, the computer 26 comprises Nematron IWS-4000 industrial micro-computer, whose mass storage is an industrial hard disc with facilities of recording over 1000 glass-bending programs. The operation of cooling fans 20 can also be adapted to be controlled by computer 26. The display of computer 26 can of course be used to optionally illustrate most versatile bending-related parameters by means of various column diagrams and symbols. Such parameters include e.g. glass and furnace temperatures, furnace heating capacity, vertical position and traveling speed of floor 8, position of roof gates 23, operating condition of fans etc.

Described next is an example of the events during a heating and bending cycle.

A glass sheet 5 is placed on a mould 6 mounted upon a carriage 7 brought out of a furnace. Carriage 7 is shifted to a position below the furnace and a protective wall 30 is lowered (fig. 2, stage b-). Carriage 7 is lifted by means of a hoist 10 to its upper position (fig. 1) and a desired bending program is selected, whereby:

- gates 23 in the roof of a furnace are closed
- a desired resistance configuration is switched on
- movable floor 8 rises to a position required by the program
- according to the rise of temperature, the program automatically switches heating resistances on or off and also adjusts the distance

of glass 5 from resistances 4

- program logic circuits 25 have been provided with set values for final glass temperature and pyrometers 21 monitor the glass temperature. Upon reaching the final glass temperature, heating is cut off and a cooling cycle commences.
- a desired cooling rate is attained by:
  - 1) controlling the number of opened gates and their degree of opening,
  - 2) controlling the speed of cooling fans 20 and
  - 3) opening a fixed floor 9 off of the lower edge of walls 2.

An essential feature in the invention is the fact that the energy distribution of a resistance field can be adjusted during a heating and bending cycle by varying it in a desired manner locally, in terms of timing and quantitatively. Thus, the heating effect can be initially focused on those bending lines which require sharp bends or a bending about two criss-crossing axes. These zones are typically adjacent to the edges of a glass sheet. However, the bending lines are not parallel, nor is the glass sheet rectangular. Nevertheless, the V-shaped arrangement of resistances 4.1 and 4.2 facilitates a correct focusing of heating effect. At the start of a bending cycle, with glass close to a heating field, the energy flux density of a mid-field section is adjusted to be substantially less than that of the fringe zones. Thus, the glass is heated and is first subjected to more vigorous bending adjacent to its fringe areas, which also require the most significant deformations (flexure and elongation). At the start of a bending cycle, the colder mid-section of glass is not yet bent at least to a substantial degree but its weight assists in the bending of fringe areas. As glass is pulled further away from a resistance field, a proportionally greater share of radiation heat is allowed to focus also on the mid-section of glass whereby, at the end of a bending cycle, the glass is bent to a required curvature also over its mid-section. Also, when using a ring mould, it is possible to employ beneath the mid-section of glass e.g. spot-like supports, which define an accurate bending configuration for glass.

Naturally, the invention is not limited to the above-discussed embodiment but a method of the invention can be applied in association with most varying glass-bending furnaces within the scope of the annexed claims.

#### Claims

1. A method for bending a glass sheet, wherein a glass sheet (5) is supported on a bending mould (6) in a heating furnace and heated close to a softening temperature by means of

- a heating field generated by heating elements (4), **characterized** in that said glass sheet (5) is placed close to a heating field whose energy flux distribution is adjusted as desired, and that said glass sheet (5) is controllably pulled away from a heating field as the glass heats up and begins to bend.
2. A method for bending a glass sheet, wherein a glass sheet (5) is supported on a bending mould (6) in a heating furnace and heated close to a softening temperature by means of a heating field generated by heating elements (4), **characterized** in that the adjustment of the energy flux distribution of a heating field and the adjustment of the distance of glass sheet (5) from a heating field are effected according to pre-established program in a manner that the combined effect of both adjustments is capable of providing a locally different and timewise varying distribution of heat-transfer effect from a heating field to glass.
  3. A method as set forth in claim 1 or 2, **characterized** in that the heating elements generating a regulable heating field comprise electric resistances (4) and that the energy flux distribution of said heating field is adjusted by switching resistances on or off and that said glass sheet (5) is pulled away from resistances (4) by lowering a bending mould (6) downwards as the glass begins to bend.
  4. A method as set forth in claim 3 or 4, **characterized** in that the energy flux distribution and the controlled pulling-away of a glass sheet are controlled according to a pre-established program.
  5. A method as set forth in claim 4, **characterized** in that the parameters of said program are experimentally searched for each bending shape and glass thickness separately and the program data is recorded in the memory of a bending-process controlling computer (26).
  6. A method as set forth in claim 1 or 2, **characterized** in that at the start of a bending cycle, with glass close to a heating field, the energy flux density of a mid-field section is adjusted to be substantially less than that of the fringe areas, whereby the glass first bends and heats more vigorously close to its fringe areas and, as the glass is being pulled away, the relative heating effect applied to the mid-section of said glass increases to such an extent that, towards the end of a bending cycle, the glass bends also over its mid-section.
  7. An apparatus for bending a glass sheet, said apparatus comprising a heating furnace (1-3), a mould (6) for supporting a glass sheet (5) in a heating furnace, as well as an array of elongated electric resistance heating elements (4), **characterized** in that the electric resistance heating elements are placed in a first and a second half-field in a manner that the longitudinal direction of elements (4.1) in the first half-field forms an acute angle with that of elements (4.2) in second half-field and that, during a heating and bending cycle, individual resistance heating elements (4) are adapted to be switched on and off according to a pre-established program.
  8. An apparatus for bending a glass sheet, said apparatus comprising a heating furnace (1-3), a mould (6) for supporting a glass sheet (5) in a heating furnace, as well as an array of heating elements (4) for generating a heating field, **characterized** in that the energy distribution of said heating field is adapted to be adjusted as desired and that the apparatus includes means (26, 12-15) for controllably pulling said mould (6) away from the heating field.
  9. An apparatus as set forth in claim 7 or 8, **characterized** in that the apparatus includes means (21) for monitoring glass temperature and that said monitoring means (21) are linked with program logic circuits (25) for controlling the energy distribution of a heating field.
  10. An apparatus as set forth in claim 7, 8 or 9, **characterized** in that the apparatus includes
    - a mould carriage (7) extractible from a furnace (3) and provided with an ascendable and descendable floor (8),
    - monitoring windows (19) and effective lighting in furnace (3) for monitoring the bending of a glass sheet (5),
    - a manually operated switch board (28) carrying separate switches (27) for switching individual resistance elements (4) on and off, and
    - a computer (26), including a program store for recording the ON/OFF-positions of switches (29) included in switch board (28) at various stages of heating and bending in a manner that the manually controlled energy distribution of a heating field and the variations thereof are programmably reproducible.
  11. An apparatus as set forth in any of claims 7 -

10, **characterized** in that the number of individual, separately switchable resistances in a heating field is over 200, preferably over 300.

12. An apparatus as set forth in any of claims 7 - 11, **characterized** in that the apparatus further includes openable and closeable cooling gates (23) in the roof of a furnace and cooling-air fans (20) mounted on the lower section of a furnace.

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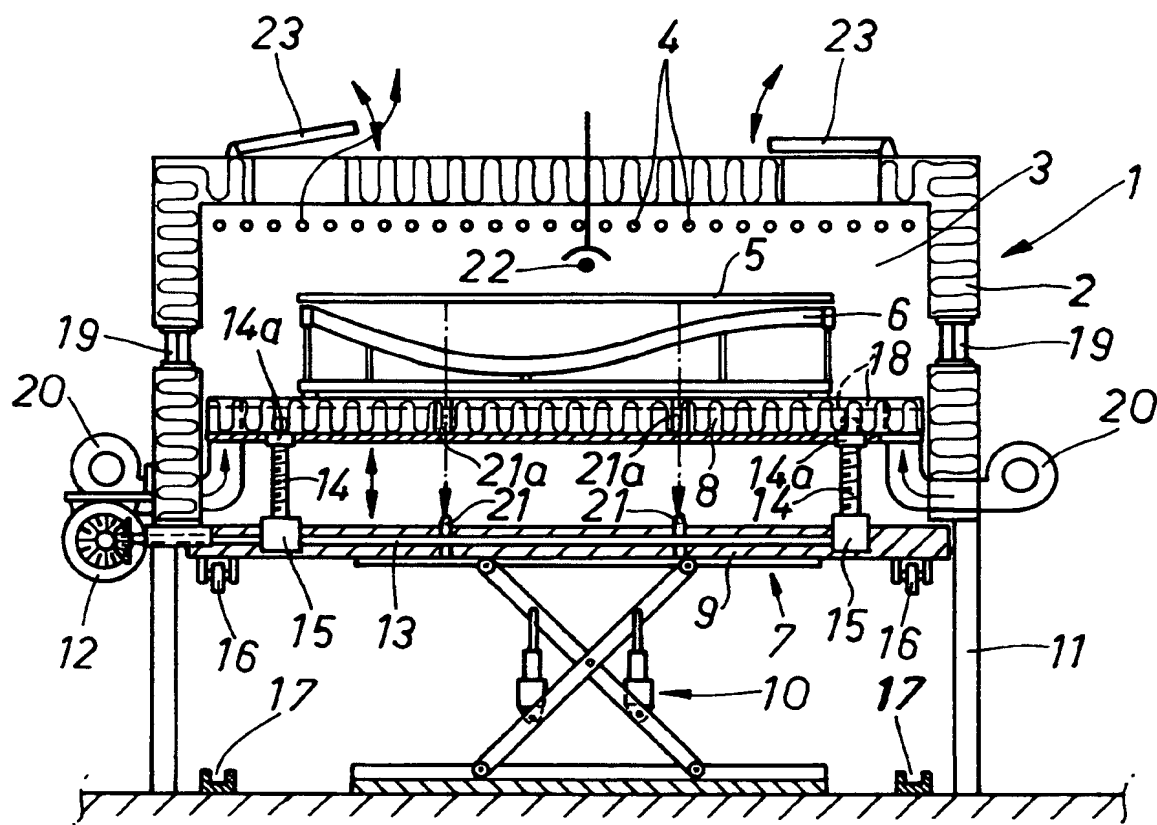
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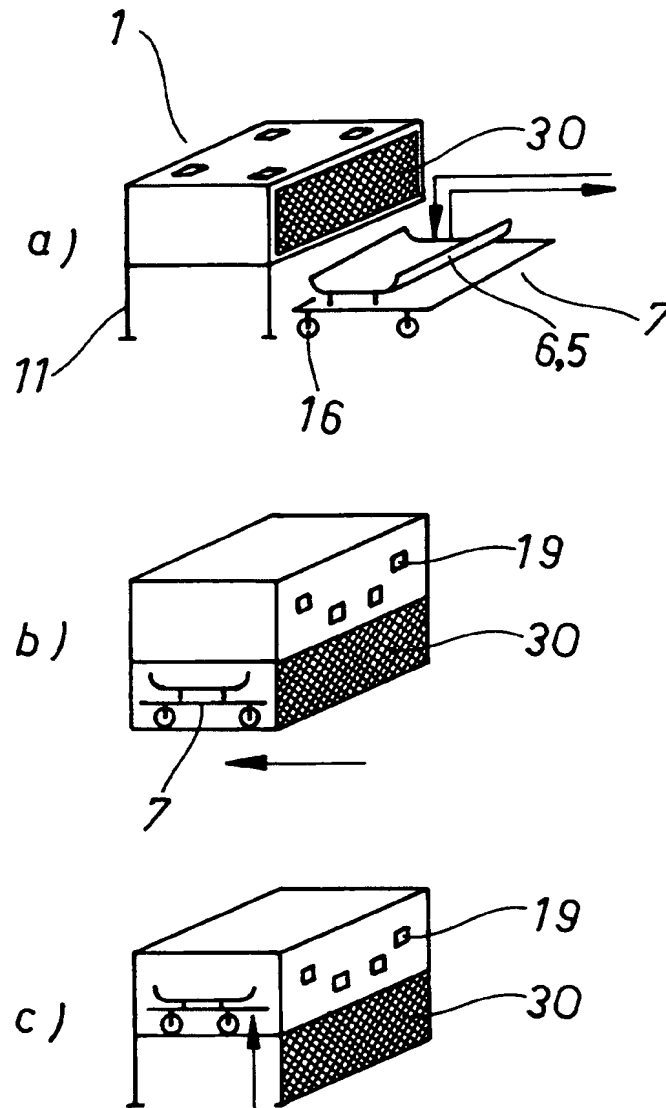
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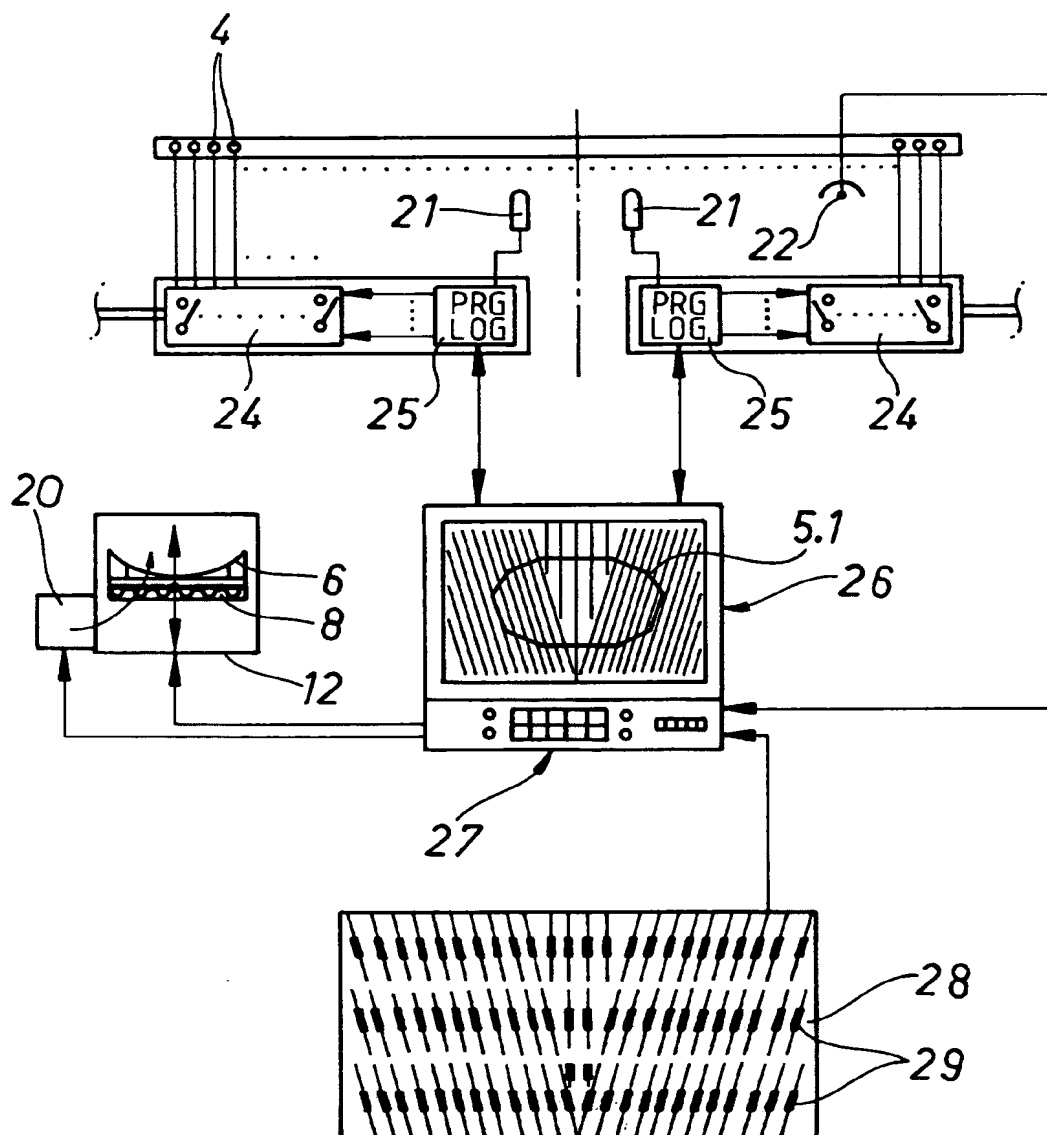
**Fig.1**

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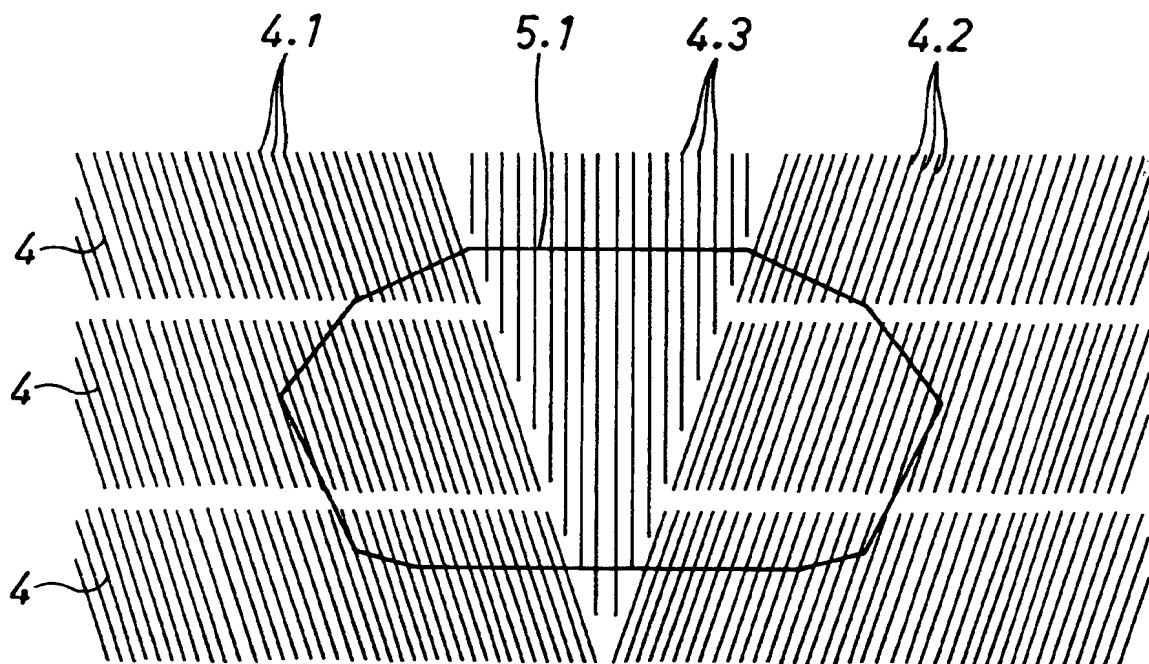


**Fig. 2**





**Fig. 3**



**Fig. 4**